INTERMITTENT IRRIGATION IN SYSTEM OF RICE INTESIFICATION POTENTIAL AS AN ADAPTATION AND MITIGATION OPTION OF NEGATIVE IMPACTS OF RICE CULTIVATION IN IRRIGATED PADDY FIELD

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ABSTRACT

Water availability that nowadays tends to decrease in quality and quantity aspects is in fact in contrary with the trend of increasing demand for water. Therefore the effort to improve water use efficiency is necessary in every aspect of life including irrigation to support agriculture, especially for paddy cultivation. Indonesia as an agricultural country has 7.49 million hectare (ha) irrigated paddy field. By means of continuous flow irrigation method, 141 billion m^3 of water is needed for irrigation during 2 planting period every year or almost 6% of water availability in Indonesia. On the other hand, one of the environmental issues related to agriculture production particularly rice is that paddy cultivation become potential contributor to global warming through methane emission. Intermittent irrigation of System of Rice Intensification (SRI) has a potential to overcome this problem. For this reason research has been conducted for four years in various implementation stages, starting from pot, field, on-farm, and tertiary unit. Water inflow-outflow, climate and methane emission data were collected in each scope for several cropping season. The result shows that intermittent irrigation of SRI has a consistent trend to have lower water requirement and lower methane emission as it is compared with conventional method using continuous flow irrigation. Water requirement was reduced by 36% in on-farm research and 15-33 % lower in a tertiary unit research. Methane emission was lower by 37.5% and global warming potential was lower by 5.7%.

Keywords: Intermittent irrigation, SRI, water requirement, methane emission

1 INTRODUCTION

1.1 Background

Water availability has been declining both in quantity and quality because of degradation of existing water resource infrastructures, continuous degradation of natural resources and most likely global warming.

It takes a serious effort to reverse the trend through various effort such as improvement of the existing infrastructures, development of additional water resources, improvement of natural resources and demand management for water.

Indonesia, has 7.49 million hectares of irrigated area which used to be planted for rice cultivation with continuous irrigation. Practical experience on paddy cultivation in Indonesia shows that average irrigation water requirement are 9,134 m^3/Ha/crop, or 141 billion m^3 of water for 7.49 million ha in 2 (two) cropping seasons. The challenge is how to improve irrigation efficiency of the existing irrigation systems and at the same time to contribute to reduction of methane emission.

1.2 Problems and Challenges

a. Continuous irrigation needs high irrigation water requirement and tends to be excessive.

b. Defisit of water are frequently happened because of long drought season and unpredictable rainfall. Competition also occurs between with not only among users in irrigation sector but also between sectors such as agriculture, raw water, and industry.

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c. Continuous irrigation with a water depth of 5~15 cm on the rice field is relatively easy to be operated, but consequently it requires higher irrigation water supply. Beside that, 5~15 cm water depth could keep the soil condition always wet and become an ideal condition for microorganism to produce higher methane emissions. With continuous irrigation patterns, operation of the gates in the field would be easier. This operation mode requires relatively large volume of irrigation water because of higher percolation rate. In addition, such a condition becomes ideal for the formation of methane gas in large quantities.

d. Those methods which caused excess water, possible to be improved to obtain higher efficiency by means of modifying water application, i.e. intermittent irrigation.

e. Up scaling at national scale in order to have significant impact on the reduction of methane emission.

f. Therefore it requires adaptive strategies that should be undertaken by all stakeholders.

1.3 Scope of Study

This paper discusses the impact of irrigation water management in paddy fields in terms of water savings and the rate of methane emissions from the farm level and tertiary level by comparing performed on paddy cultivation between continuous and intermittent irrigation management.

2 OBJECTIVE AND GOAL

2.1 Objectives

a. To obtain the description of the impact of continuous and intermittent irrigation water management in paddy fields in water saving and methane gas emissions both at the field and tertiary level.
b. To develop water saving irrigation system as one of adaptation and mitigation strategies to face global climate change.

2.2 Goals

a. To get the value of water savings and the rate of methane emission from the pattern of irrigation water management in paddy fields at the farm level and tertiary level.
b. To get the value of water productivity (weight in kg/1 m^3 of water) in intermittent and continuous irrigation.

3 METHODOLOGY

3.1 Method of Study

3.1.1 Irrigation Water Treatments

Experimental Station for Irrigation has conducted a series of water-saving irrigation research on *System of Rice Intensification* (SRI) method of paddy cultivation in pot trials, field trials and on-farm activities in the farmer's field and the tertiary level. The results obtained from the study is the planning parameters for the operation patterns of SRI in irrigated land .The pattern of water supply and other parameters were then used to plan irrigation operations on a larger scale.

In this paper, water parameters data and water supply pattern were collected from research which conducted at the field laboratory Lemah Abang, Bekasi district in the second cropping season in 2007 (dry season). Meanwhile, for the tertiary level, the observation was conducted in 2008-2009 in Tertiary of Cimanuk irrigation scheme (BCMK 5 Ki) Tasikmalaya, West Java. The water treatment used is the water treatment SRI West Java (A1) and conventional. Figure 1 show the water treatment in a simple pattern both of field level and tertiary level. Patterns of water delivery in tertiary conducted at intervals of five daily. In less of water availability conditions were done rotations at quarter level. Production data was taken with the plot method.

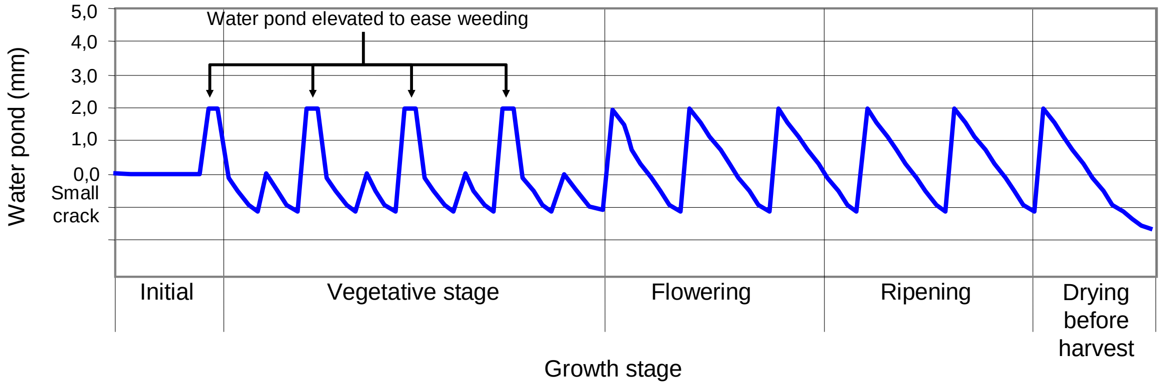

Figure 1 Scheme of SRI water supply (Experimental Station for Irrigation, 2008)

Figure 2 Condition of soil at shallow pond of 2 cm (left) saturated soil (middle) and hair cracks (right)

3.1.2 Water Productivity

Water productivity was obtained by comparing the water consumption for one planting season to yield data (m^3 water / kg yield). Water consumption is calculated based on the pattern of the intermittent water treatment as in Figure 1. As a comparison it is also measured for continuous irrigation.

3.1.3 Methane Emission

Primary data were collected for concentration of methane gas parameters of water, methane gas parameters and the other supporter parameters. Parameters consist of the local climate data, soil moisture and plant data (growth phase until harvest). Secondary data obtained from other parties and literature / references associated with the irrigation patterns and methane emission from paddy fields. Flux of greenhouse gases (CO_2, N_2O and CH_4) were measured on a three-phase growth of rice plants is the active till ring stage, primordial and flowering. CH_4 emissions are not only out through the bubbles of air and soil pores, but also out through parenchyma vessels of rice plants in the process of photosynthesis.

All the primary and secondary data collected were analyzed quantitatively. Gas concentrations of gas samples were analyzed using gas chromatography or GC. CH_4 were analyzed using Shimadzu GC 8A equipped with a Flame Ionization Detector (FID).

3.2 Literature Review

Paddy field is a term that shows how to manage different types of land for paddy cultivation which is physically characterized by the formation of oxidative or aerobic layer above the layer beneath it reductive or anaerobic as a result of over flowing (Patrick and Reddy, 1978;

Ponnamperuma, 1985 in Untung Sudadi, 2002). According to Greenland (1997), IRRI classify wetland ecosystems as paddy soil irrigated with surface features, flat land, bordered by a small dike with water controlled, land inundated by shallow with the dominant anaerobic soil conditions for crop growth and planting rice seedlings on muddied soil.

Irrigation and drainage water management is an important practice in rice cultivation. In most of paddy field land, growth of paddy plant will be disturbed by surplus or water shortage conditions. According to Government Regulation Number 20/2006 about irrigation, irrigation is defined as the effort to providing, regulating and drainage the disposal of irrigation water to support agriculture. In certain conditions the plant needs additional water. Amount of water allocation in plants depends on climate, soil type, water availability in the soil, the crop water requirement (ETC), and the habits of farmers. According Kartasapoetra and Mul (1983), the supply of water in the plot of rice could be done by continually flooding and intermittent. The first way is usually done when the availability of water was enough for water requirement in the field. Regional Irrigation Jatiluhur West Java with service area more than 237 thousand ha, the water is needed now 10 000 ~ 12 000 m^3/ha/MT. So to be able to irrigate all the service area in one year, it needed at least 2.37 ~ 2.84 billion m^3 of irrigation water. The second way is done when the water availability is insufficient irrigation water requirements in the field. So it can be said that in many cases, intermittent irrigation is done because of a compulsion due to lack of availability of water. However, through the planned and executed well of intermittent irrigation, irrigation water savings can be achieved. This number will be greater if it is conducted with a maximum height of water in paddy field such as ± 2 cm which were conducted on rice cultivation using the System of Rice Intensification (SRI). From the results of advanced research at the 2008 rainy season and dry season in Lemah Abang, Bekasi district, intermittent irrigation pattern is in the SRI can save water consumption at the field level average of 35% compared with the continuous one.

Flooding becomes specific characteristic of irrigated paddy field land system. In this condition, high oxygen requirement compared to low availability rapid caused the form of two very different soil layers i.e.: oxidative/aerobic surface layer where free oxygen is available and reductive/anaerob layer where no free oxygen is available. Methane emission from paddy field basically determined by two difference microbial process, that is: methane production and methane consumption (Rud and Taylor, 1980). In paddy field, methane is produced as the intermediate and final output of various microbial processes (Zehnder and Stumm, 1988) such as anaerobic de-composition of organic material by methanogen bacteria. This bacteria is active only due to reductive or anoxic soil condition is achieved through water pounding. A part of produced methane will be oxidated by methanotroph bacteria with their aerobic characteristic at the soil surface layer and root zone. The remains anoxidated methane is transferred into the atmosphere by diffusions through pounding water, ebullition or formed gas bubbles and transported through paddy parenchyma.

Table 1 Representative Global Annual Methane Emission from Paddy Fields

Reference	Estimate	
	(Tg CH4/yr)	(kg CH4/yr)
Koyama (1964)	190	$1{,}90.10^{11}$
Ehhalt and Schmidt (1978)	280	$2{,}80.10^{11}$
Cicerone and Shetter (1981)	59	$5{,}9.10^{10}$
Khalil and Rasmussen (1983)	95	$9{,}5.10^{10}$
Seiler at al. (1984)	35-59	$(3{,}5\text{-}5{,}9).10^{10}$
Blake and Rowland (1988)	142-190	$(1{,}42\text{-}1{,}90).10^{11}$
Crutzen (1985)	120-200	$(1{,}20\text{-}2{,}00).10^{11}$
Holzapfei-Pschorn and Seiler (1986)	70-170	$(7{,}0\text{-}17{,}0).10^{10}$
Cicerone and Oremland (1988)	60-170	$(6{,}0\text{-}17{,}0).10^{10}$
Schutz et al. (1989)	50-150	$(5{,}0\text{-}1{,}50).10^{10}$

Reference	Estimate (Tg CH4/yr)	(kg CH4/yr)
Aselman and Crutzen (1989)	60-140	$(6,0\text{-}14,0).10^{10}$
Schutz et al. (1990)	50-150	$(5,0\text{-}15,0).10^{10}$
Wang et al. (1990)	60-120	$(6,0\text{-}12,0).10^{10}$
Neue et al. (1990)	25-60	$(2,5\text{-}6,0).10^{10}$
Bouwman (1990)	53-114	$(5,3\text{-}11,4).10^{10}$
Yagi and Minami (1990)	22-73	$(2,2\text{-}7,3).10^{10}$
IPCC (1990)	25-170	$(2,5\text{-}17,0).10^{10}$
Minami (1994)	12-113	$(1,2\text{-}11,3).10^{10}$
Sass (1994)	25-54	$(2,5\text{-}5,4).10^{10}$
Parashar et al. (1994)	20	$2,0.10^{10}$
IPCC (1996)	20-100	$(2,0\text{-}10,0).10^{10}$

Source: Minami, 1994 in IPCC Guidelines for National Greenhouse Gas Inventories

On his research report, Setyanto (2005 – 2006) mentioned that through intermittent irrigation method, methane emission on paddy field can be reducing about 27% – 62% compared with continuous irrigation method. This research conducted during dry season (March – June) of 2002 at farm research in Jakenan, Central Java (Table 2). Three observed irrigation pattern consist of continuous irrigation and intermittent irrigation with following respective treatment; i.e: (i) to be continually flooding during growing period at the height 5 cm/continuous flooded (CF); (ii) intermittent irrigation 1/ intermittent irrigation (II) where paddy field to be flooded 5 cm during growing period but to be dried up 2 (two) times at 15 – 20 DAT (days after transplant) and 25 – 30 DAT; (iii) intermittent irrigation 2/ pulse irrigation (PI) on which paddy field to be flooded up to 5 cm then to be left until the height of water in the soil about 30 cm below soil surface, finally to be flooded again up to 5 cm, etc.

Table 2 Total CH_4 emission and yield under four different water regimes at Jakenan Experimental Farm during the dry season of 2002

No	Water regimes	CH_4 Emission (kg/ha)	Yield (kg/ha)
(i)	5 cm (continuous flooded)	254	3482
(ii)	1 cm (saturated irrigation)	185	2990
(iii)	intermitten irrigation	136	3529
(iv)	pulse irrigation	96	2986

Irrigation method (iii)/ pulse irrigation gave methane gas reduction up to 62,6% compared with irrigation method (i)/5 cm continuous flooded, while irrigation method (ii)intermittent irrigation can mitigate the rapid of methane gas emission about 46,5% respectively.

According to Shin *et al* (1996), intermittent irrigation methods can reduce methane emissions by 36% compared to the flooding method. While the use of which has been decomposed compost well before planting can reduce methane emissions by 49% compared to put fresh straw into the paddy field. Water supply pattern was conducted by flooded application during the 30 days after transplant (DAT) and two weeks before harvest. Intermittent irrigation is done until the visible hair cracks in the surface soil.

According to Yang and Chang (2000), seasonal methane emission from paddy fields ranged from 1.73-11.7 g/m^2 and 10.54-39.50 g/m^2 respectively in the first cropping season and the second cropping season. Seasonal methane emission was 32.65 mg/m^2 in the first cropping season flooded with irrigation and 28.85 mg/m^2 in the second cropping season. The annual methane emission in the intermittent irrigation is 12.3 - 49.3 g/m^2, while the flooding irrigation is 61.5 g/m^2.

Some paddy cultivation technology currently develops and one of them is the SRI. SRI has several advantages which are able to economize use of water during growing period from planting until harvest time an average of 38% at the farm level, while at the tertiary level reaches 15-33% savings without reducing production significantly.

According to Zhao, *et al* (2010), at the farm level SRI cultivation pattern has a higher grain production of 26.4% compared with the traditional flooding. Compared with flooding pattern SRI improves water use efficiency of 91.3% and it has 194.9% irrigation efficiency.

SRI is one of the rice cultivation with intermittent irrigation water management with the shallow flooding maximum of 2 cm and use the small dike around (temporary drainage), using organic fertilizers and bio pesticides. Actually this way is a way that has long been done by farmers at the past. With SRI, rice root zone management was integrated from the aspect of water, plants, soil and the other soil nutrient elements. So that it can be said that beside of saving water, SRI can increase the productivity of rice plants with an environmentally friendly manner.

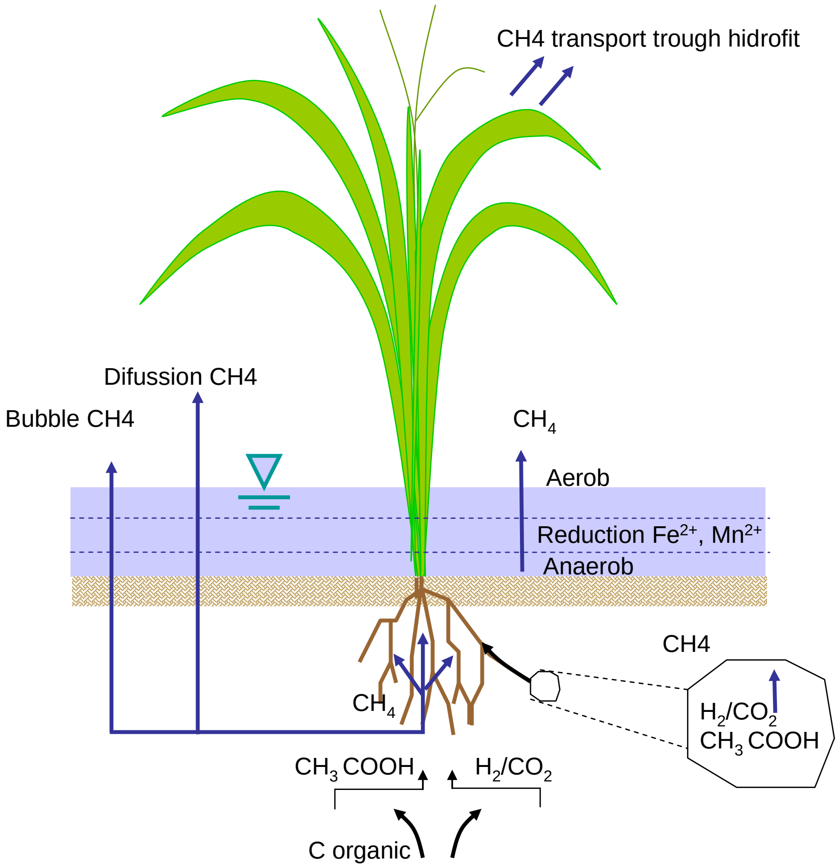

Figure 3 Chart the formation of methane in paddy soil and disposal into the atmosphere (Takai and Wada, 1990 in Muqorrobin, 2008)

4 FIELD OBSERVATION OUPUT

4.1 Irrigation Efficiency

The result of field research conducted during the dry season 2007 on Field Laboratory at Lemah Abang shows that water efficiency in paddy cultivation (SRI method) through intermittent irrigation reached is in average 45% of that with conventional method. Two observed irrigation pattern consist of (1) to be continually flooding during growing period at the height 5 cm/continuous flooded (K) and (2) intermittent irrigation with paddy field to be flooded up to 2 cm then to be left until the soil moisture reach up to 80% of saturated capacity, then to be flooded again up to 2 cm, etc (S). By intermittent irrigation, potential water efficiency in SRI method reached up to 54% with the yield of 6 ton /Ha. From the three conducted repetition, water consumption by intermittent reached about 430,9 mm/Ha while irrigation by conventional method reached about 784,43 mm/Ha (Table 3).

Table 3 Irrigation water consumption and productivity under two different water regimes on Field Laboratory at Lemah Abang, Bekasi during the dry season of 2007

Water Regimes	Repetition	Water Consumption (mm/ha/cropping season)		Yield (t/ha/cropping season)		Water productivity (kg yield/m³ water)
		Repetition	Average	Repetition	Average	
SA1 (SRI)	1	493,20		6,00		
	2	476,90	430,40	5,90	5,80	1,35
	3	321,10		5,50		
KA4	1	877,10		6,20		
(Conventional)	2	767,50	784,43	5,90	6,10	0,78
	3	708,70		6,20		

Tertiary level study was conducted at CMA-5 Ki in Tasikmalaya, West Java at second cropping season in 2008. About 44% of the tertiary area implemented SRI and the remaining 56% implemented conventional cultivation. With that percentage, the total water consumption requirement for the entire plot of a tertiary is 561 mm. This number is 274 mm lower than if the entire plot applies conventional cultivation (835 mm). Water savings incurred is 33% compared to conventional. The yield of SRI in this study of the second cropping season was fairly well.

Table 4 Cropping area of SRI and conventional in second cropping season in 2008

Quarter	SRI		Conventional	
	ha	Percentage	ha	Percentage
1	0,00	0.00	2,15	12.07
2	1,08	6.06	4,58	25.72
3	3,62	20.32	0,21	1.18
4	3,21	18.02	2,96	16.62
Total	7,92	44.41	9,90	55.59

4.2 Methane Emission

Beside irrigation water efficiency, observations were carried out on methane emissions resulting from the two treatments mentioned above. Intermittent irrigation pattern in SRI can reduce methane emissions to an average of 60% that of the conventional continuous irrigation patterns, based on the field data. While based on research results obtained at the tertiary level that the water-saving irrigation SRI produces lower CO_2 equivalent emissions than conventional one. Global warming potential (GWP) values ranged from 14.9 - 31.9 t CO_2 equal/ha/season. The value of GWP with SRI method is 5.7% lower than the conventional way.

Table 5 Methane emission with two different water regimes in field laboratory in Lemah Abang, Bekasi in dry season 2007

Water Regimes	Repetition	CH_4 Flux (mg CH_4-C m^{-2} $hour^{-1}$) day- (DAT)				
		27	41	55	69	83
SA1 (SRI)	1	1.3832	0.3235	1.3341	0.6281	0.4604
	2	2.3495	1.9847	-0.2020	1.1047	0.9641
	3	0.8909	2.8305	1.6468	0.8150	-0.7292
	Average	1.5412	1.7129	0.9263	0.8493	0.2318
KA4 (Conventional)	1	12.6282	-0.0756	-0.0585	0.6436	-0.0633
	2	4.1367	0.6771	12.0086	5.0571	0.1361
	3	0.1739	2.2536	3.3024	-0.9039	0.0705
	Average	5.6463	0.9517	5.0842	1.5990	0.0478

Table 6 Methane gases emission in tertiary plot of CMA 5 Ki in first cropping season 2009

Plot	Total emission (kg/ha/MT)			GWP	Yield	Indeks (GWP/yield)
	CH_4	N_2O	CO_2	(t CO_2 eq)	(t/ha)	
Plot 1 (Conventional)	189.3	1.42	15752	20.5	3.5	5.86
Plot 2 (SRI)	22.0	4.88	14380	16.3	3.6	4.54
Plot 3 (SRI)	142.5	1.36	11192	14.9	3.6	4.13
Plot 4 (SRI)	128.2	1.41	12672	16.0	3.5	4.58
Plot 5 (SRI)	208.9	1.39	26655	31.9	4.7	6.78
Plot 6 (SRI)	90.2	1.64	15282	17.8	5.8	3.08

5 DISCUSSION

5.1 Irrigation Efficiency

Distributing water by intermittent irrigation method offer beneficial to water efficiency, more over it can also mitigate methane emission. From the observation in the field area, obtained that through intermittent irrigation, potential water efficiency up to 54% (average 45%) compared with conventional method. Intermittent irrigation needs only 321.10 mm/ha water, while by continuous irrigation 708,7 mm/ha water needed. Mean while, at the tertiary level water could be save by 33%. Total water requirement for all tertiary unit is 561 mm with intermittent irrigation, whereas for conventional irrigation 835 mm.

The efficiency of water is not automatically influencing field productivity. Beside, the amount of water to be efficiently used will be beneficially if it is applied at least in one tertiary block so that such amount of water saving can be used for irrigation at the downstream tertiary. In the irrigation system where the resource of water come from dam/weir, efficient water will be useful to enlarge service area, furthermore it can be used for various activities than agriculture such as: settlement, rural drinking water, which to be integrated with drinking water technology, industry, etc.

5.2 Methane Emission

During the growing period, the rate of methane emissions in the intermittent irrigation was decreased as it is compared with continuous irrigation. In the treatment of intermittent irrigation pattern at Field Laboratory Lemah Abang, Bekasi, the rate of methane gas emission ranged from 1.76 to 16.57 mg CH_4-C/m^2.day. While with continuous irrigation its emission ranges from 4.64 to 23.10 mg CH_4-C/m2.day. Methane emission reduction occurred an average of 60% compared with continuous irrigation. Setyanto (2005 & 2006) in his research in Jakenan, Central Java on dry season in 2002 noted that with the intermittent irrigation (saturated, intermittent and pulse Irrigation) methane emissions can be reduced to 62.6% compared with continuous irrigation with 5 cm flooding. This is quite appropriate with the result of research conducted at the Texas Rice Fields, USA. Sass et.al (1992), in her study she compared four irrigation patterns with the rate of methane emissions. Actually the normal flooding combining with several times drainage (intermittent Irrigation), the rate of methane emissions can be reduced up to 88% compared with the normal pool without drainage.

With the treatment intermittent irrigation in tertiary plot, the CH_4 flux measurements during the three phases of the growth of rice plants showed a diverse pattern. Table 6 shows that the total CH_4 emission during a season varies with the range of between 22-208 kg (average of 130.2 kg). From this research, emissions of CH_4 on SRI method decreased by 37.5% compared with the conventional method.

Global warming potential of each greenhouse gas is different one to another. The study shows that the global warming potential (Global Warming Potential, GWP) for CH_4 is 23 times higher than CO_2, and N_2O is 296 times higher than CO_2. Therefore, all greenhouse gas CO_2 will be synchronized with its value (usually expressed as CO_2 equivalent, or abbreviated with CO_2-eq). From the calculation of GWP values were ranging from 14.9 to 31.9 t CO_2-eq/ha/musim. From Table 6 also shows that the GWP for the way conventional farmer's cultivation is 5.7% higher than SRI method. This shows that the way in Ciramajaya SRI, equivalent to CO_2 emissions was lower than the conventional way. The low emissions of CO_2-eq on the way SRI alleged to be caused by intermittent irrigation means that potentially reduce CH_4 emissions by an average of 37.5% compared to the way continuous irrigation.

Results of emission index calculations showed that the rice yield conventional cultivation produce 5.9 and SRI method index ranged from 3.1 to 6.9 (average 4.6). The results of this study indicate that in the SRI method having emissions production index is lower than the conventional method by farmers. This shows that the emission of greenhouse gases on the SRI method is lower than the conventional way.

Basically paddy doesn't need a flooding condition during the growing process. This research is appropriate with studies in Jakenan which show that a reduction volume of water flowed into the paddy field did not affect rice production. In addition, the management of irrigation water can affect the pH, chemical reactions, and activity of soil microorganisms associated with greenhouse gases emissions (Setyanto, 2004).

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Intermittent irrigation has potential to save water. The result of field laboratory at farm level shows that intermittent irrigation saved water 54% comparing with continuous irrigation. Crop water requirement for intermittent flow was 321.10 mm while for continuous flow was 708,7 mm. At tertiary level intermittent irrigation saved water 33% comparing with continuous irrigation. As crop water requirement for intermittent and for continuous flow was 561 mm and 835 mm respectively.

Though intermittent (SRI) irrigation would save irrigation water significantly, but these would not affect the productivity of paddy, as higher productivity at SRI would be achieved at the third crop. However water productivity for intermittent (SRI) irrigation was 1.35 kg paddy/m3 water and for continuous irrigation was 0.78 kg paddy/m3 water. It shows that water productivity increased 78%.

Intermittent irrigation can be used as mitigation of negative impacts of paddy cultivation in the irrigated rice fields. It can reduce the rate of methane emissions in the range 1.76 ~ 16.57 mg CH_4-C/m^2.day while with continuous irrigation ranges from 4.64 ~ 23, 10 mg CH_4-C/m^2.day, according to the results of research in the field. Methane emission reduction occurred an average of 60% compared with continuous irrigation. While at SRI research in a tertiary level CH_4 emissions decreased by 37.5% compared with the conventional method. GWP values ranged from 14.9 to 31.9 t CO_2-eq/ha/season. GWP for the conventional method is 5.7% higher compared to the SRI method.

6.2 Recommendation

Intermittent irrigation in rice cultivation can be used as an act of adaptation to limited water availability as well as mitigation measures against negative impacts of rice cultivation to the environment.

Support from various parties are needed in the implementation of intermittent irrigation methods at farm level so the adaptation and mitigation efforts could provide benefits to farmers.

Further study is needed regarding the water management of intermittent application at irrigation schemes level. Those intermittent irrigation methods require more knowledge and understanding, both to workers who observe the water, and the farmers.

7 REFERENCES

Ministry of Public Works. *Peraturan Menteri Pekerjaan Umum Nomor 32/PRT/M/2007 Tentang Pedoman Operasi dan Pemeliharaan Jaringan Irigasi.*

IPCC. *Guidelines for National Greenhouse Gas Inventories : Reference Manual*. 1996 page 4.60.

Limei Zhao et all. *Comparison of Yield, Water Use Efficiency, and Soil Microbial Biomass as Affected by the System of Rice Intensification.* Communication in Soil Science and Plant Analysis, Volume 41, Issue 1 January 2010 page 1-12.

Setyanto, P.; *Evaluation of Methane Emissin and Potential Mitigation from Flooded Field*. Jurnal Litbang Pertanian; Juni 2006.

Setyanto, P.; *Perlu Inovasi Teknologi mengurangi Emisi Gas Rumah Kaca dari Lahan Pertanian*. Sinar Tani; April 2008.

S.-S. Yang dan H.-L. Chang. *Methane Emission from Paddy Field in Taiwan.* Springer-Verlag. 2001

Experimental Station for Irrigation Team. Penelitian Irigasi Hemat Air pada Budidaya Padi dengan metode SRI di lahan petani Tasikmalaya (MT 2/2007). Buku 8, Seri Penelitian Irigasi Hemat Air pada Budidaya Padi dengan metode SRI, Balai irigasi; September 2007.

Experimental Station for Irrigation Team. Penelitian Irigasi Hemat Air pada Budidaya Padi dengan metode SRI di laboratorium lapangan/ field trial (MT 2/2007). Buku 11, Seri Penelitian Irigasi Hemat Air pada Budidaya Padi dengan metode SRI, Balai Irigasi; Oktober 2007.

Experimental Station for Irrigation Team. Penelitian Irigasi Hemat Air pada Budidaya Padi dengan metode SRI di laboratorium lapangan/ field trial (MT 1/2008). Buku 13, Seri Penelitian Irigasi Hemat Air pada Budidaya Padi dengan metode SRI, Balai Irigasi; 2008.

Experimental Station for Irrigation Team. Penelitian Irigasi Hemat Air pada Budidaya Padi dengan metode SRI di laboratorium lapangan/ field trial (MT 2/2008). Buku 15, Seri Penelitian Irigasi Hemat Air pada Budidaya Padi dengan metode SRI, Balai Irigasi; 2008.

Experimental Station for Irrigation Team. Penelitian Irigasi Hemat Air pada Budidaya Padi dengan metode SRI di Petak Tersier, Tasikmalaya (MT 2/2008). Buku 17, Seri Penelitian Irigasi Hemat Air pada Budidaya Padi dengan metode SRI, Balai Irigasi; 2008.

Experimental Station for Irrigation Team. Penelitian Irigasi Hemat Air pada Budidaya Padi dengan metode SRI di Petak Tersier, Tasikmalaya (MT 2/2009). Buku 22, Seri Penelitian Irigasi Hemat Air pada Budidaya Padi dengan metode SRI, Balai Irigasi; 2009.

Yong-Kwang Shin et al. *Mitigation Option for Methane Emission from Rice Field in Korea*. Ambio Vol 25 No.4, Juni 1996. Royal Swedish Academy of Science.

Untung Sudadi; *Produksi Padi dan Pemanasan Global: "Tanah Sawah Bukan Sumber Utama Emisi Metan*". Makalah Pengantar Falsafah Sains Pasca Sarjana IPB; Juni 2002.